



ORGANICS IN ONTARIO DRINKING WATERS

PART II A SURVEY OF SELECTED WATER TREATMENT PLANTS

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Minister

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Deputy Minister

ORGANICS IN ONTARIO DRINKING WATERS

PART II*

A SURVEY OF SELECTED WATER TREATMENT PLANTS

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- * Part I: The Occurrence and Determination of Free and
Total Potential Haloforms.

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ABSTRACT

The survey of organics in Ontario drinking waters was initiated in late 1974. The laboratory concentrated efforts on the determination of compounds that had been found previously in drinking water elsewhere and are either suspected or known to be toxic.

Both "Free" and "Total Potential" haloforms were determined at 48 different water treatment plants throughout the Province. Brantford was found to have the highest average "Total Potential" chloroform concentration of 159 parts per billion. The haloform levels were correlated to the various raw water sources. Seasonal variation in chloroform concentration was correlated with the temperature of the raw water.

Herbicides, pesticide and polychlorinated biphenyl (PCB) concentrations were determined at 27 water treatment plants. Atrazine was found in the finished water at 8 locations, with the highest level being 0.45 parts per billion. No PCBs were found. Pesticides in trace quantities (parts per trillion) were found in 3 drinking water supplies. However, their identification could not be substantiated by mass spectrometry because of the very small quantities found.

Gas chromatographic/mass spectrometric analysis of finished water from 14 locations revealed, apart from haloforms, trace quantities (parts per trillion) of aromatic hydrocarbons in 5 locations.

FOREWORD

Recognizing the environmental importance of organic contaminants, the Ministry of the Environment laboratories have, during the past decade, gradually increased diagnostic and analytical capabilities in the field of organic trace analysis. During 1974, the increasing number of reported occurrences of volatile organohalides in drinking waters and their apparent connection with the widely used water disinfection process (chlorination) prompted us to devise a plan to monitor Ontario drinking waters for volatile organohalides. The plan also called for the analysis of drinking waters for the possible presence of pesticides, herbicides and PCBs and to carry out general scans for volatile organics using gas chromatography/mass spectrometry.

The sampling locations were chosen to encompass raw water sources from the Great Lakes System, ground water, and lakes and rivers apart from the Great Lakes System.

In addition to the province-wide monitoring of drinking waters, various stages of the water chlorination process were investigated at some water treatment plants to obtain information about the kinetics and mechanism of the haloform producing chemical reactions. Seasonal variations in haloform levels were also followed at selected locations. Simultaneously, various water treatment methods were investigated in order to develop technology for the removal of haloforms from drinking water or to prevent or minimize their formation. A separate report on the results of these investigations is in preparation.

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INTRODUCTION

General

Organic compounds can enter raw water sources for drinking water from a wide variety of sources. Surface waters may be contaminated by organic chemicals discharged in the waste effluents from various industries, run-off waters and natural degradation products. Chlorinated compounds may be among industrial waste effluents or are produced by the chlorination process used to disinfect both industrial and domestic sewage treatment plant effluents. Run-off from agricultural land can introduce toxic biocides into lakes, rivers, and streams. The organic load in raw water sources in non-industrialized areas is derived primarily from the biological degradation of plant and animal matter.

Ground water sources can, in some cases, contain significant amounts of organic matter. Connection of the aquifer to a polluted surface water is the most obvious source of contamination, but ground waters can also be polluted by water leaching from landfill sites, deep well injection disposal, or chemical spills on the surface.

Many of the organic compounds found so far in drinking water are present in very low concentrations (less than 1 mg/l level). These organics have escaped detection and identification until very recently when new instrumentation and analytical techniques were developed. The presence of organics was previously considered a matter of concern only when they affected either the appearance or the taste and odour of drinking water, making it unacceptable to the consumer.

A number of methods are presently available to the organic analytical chemist for monitoring the organic content of water. General parameters such as chemical oxygen demand (COD), biological oxygen demand (BOD), and total organic carbon (TOC) give some information on the overall organic load.

Since the two former methods have detection limits in excess of 20 mg/l, they were not applicable to drinking water analysis. The TOC method is now in most general use for monitoring the total organic loading of water.

Historical Background

Since organic compounds can cause taste and odour problems at levels much lower than the detection limits of these methods, the carbon adsorption method (CAM) was developed in 1951 by the United States Public Health Service (1). This method involved passing large volumes of water through a carbon column, drying the carbon, and then extracting it with selected organic solvents. The standardized procedure (2) involved extraction with chloroform and subsequently alcohol, evaporating the solvent from each of the extracts, and weighing the solvent extractable residues. As well as giving an indication of the loading of the organic compounds in water, the availability of the extract enabled the chemist to do further work in isolating and identifying individual organic compounds present.

In early work, Middleton and co-workers separated the extract into acid, base and neutral fractions (3,4) and found that the compounds causing odour problems were volatile aromatic hydrocarbons and oxygenated neutral materials.

Since only a few grams of organic material could be obtained from the carbon chloroform extract (CCE), and a large number of compounds were known to be present, the Mega sampler (CAM) was introduced in the early 1960's (5). Using this device, up to 1.7 kg of organic extract was obtained from 1.2 million litres of water. This extract was then used for both chemical characterization and physiological studies.

Over the years, the CAM has undergone a number of refinements (6) making the sampling and the extracts easier to handle. Using this method, a number of observations were made about the effect of water treatment on the organic chemical loadings in the raw water. Tomlinson (7) noted that after water treatment, the CCE increased instead of decreasing as might have been expected. Using the Mega sampler Rosen, et al. separated and identified eleven odour causing compounds in a polluted river (8). A number of pesticides were also found in low concentration (9) in a raw water source.

One of the more dramatic studies of carbon filter extracts of an Evansville, Indiana drinking water was made by Kleopfer and Fairless (10). They separated 40 organic compounds using gas chromatography, and identified 13 of these by gas chromatograph/mass spectrometry (gc/ms).

Although the carbon filter method gave the organic analyst an overview of the organic compounds present, a number of problems were still associated with this technique. The CAM sampler gave very poor recoveries for organophosphorous pesticides (11), and also for some organochlorine pesticides. Change in flow rate through the cartridge produced changes in the amounts of organics absorbed (12).

Water/carbon interactions influenced values obtained for blanks (13) and difficulty was experienced in the desorption of some compounds (14).

With the concern over the increasing number of potentially toxic man-made chemicals entering the environment and the availability of more sophisticated analytical instrumentation, the disadvantages of the CAM were becoming more and more apparent. This promoted the development of a considerable number of new techniques for measuring trace levels of organic compounds in drinking water.

Modern Analytical Techniques

For the analysis of complex mixtures, the gas chromatograph (gc) has become one of the most powerful tools available to the environmental analyst. The development in recent years of highly specific gc detectors has permitted the determination of very low (1 ng/l) concentrations of some substances such as organochlorine pesticides, herbicides and polychlorinated biphenyls using simple liquid-liquid extraction of relatively small samples. Because of the specificity of the detectors, many other compounds present in the water are overlooked. To remedy this situation, gc/ms analysis was developed. Unfortunately, although it is a universal detector, the mass spectrometer is not nearly as sensitive as the electron capture or electrolytic conductivity detectors. To overcome this difficulty, many new concentration techniques have been developed in the past 10 years.

(a) Head Space Analysis

Most of the new techniques developed involve the analysis of relatively volatile organic compounds in drinking water. The most promising method for producing high concentration factors appears to be the head space, or modified head space sampling technique, which involves analysis of the compounds above the surface of the sample held in a closed vessel. Silvey et al. (15,16) concentrated odours given off by actinomycete bacteria (a common cause of the musty odour in drinking water) by passing a stream of nitrogen over the surface of the bacterial culture and the target organics in the gas stream were then collected by bubbling the gas through either methylene chloride or water.

(b) Use of Solid Sorbents for Concentration of Organics

A significant improvement in the head space analysis technique occurred when several researchers started using solid absorbents as traps. Rook (17) used a 10 liter drinking water sample from the Rhine River and flushed the head space gas through a silica trap. Following thermal desorption, twenty organic compounds were identified, including a large number of chlorinated species.

Grob (18) developed an extremely elegant, closed loop sparging system, which involved passing the purged head space gas through a micro-carbon filter, and back through the 5 liter sample. Concentration factors of up to 10^6 times were obtained for compounds containing up to 24 carbon atoms.

Further improvements and simplifications in the method (19,20,21) reduced the sample size to one litre.

Zlatkis et al. (22) and Mieure et al. (23) concentrated the head space gas by continuously flushing it through a porous polymer trap, and subsequently desorbed the trapped organics thermally for analysis.

Bellar (24) used a 5 ml sample and the gas sparging technique, trapping the organics in drinking water on a "Tenax GC" trap, and, subsequently, analysing the organics by gas chromatography. Kopfler et al. (25) used a 500 ml sample and an apparatus similar to that used by Bellar for both quantitative and qualitative analysis by gc/ms.

Although most of the effort has been directed towards head space analysis, considerable effort has been expended to develop new methods for directly absorbing the organics from water. Macroreticular resins have recently become very popular for this work, owing to the efforts of Junk and his co-workers on XAD resins (26,27). These researchers and Glaze (28) have made extensive use of the XAD-2 technique for the analysis of organics in drinking water.

(c) Miscellaneous Concentration Techniques

Several authors have also developed apparatus for the continuous liquid-liquid extraction of large volumes of water, in a flow-through system (29,30,31) to give high concentration factors.

Grob (20) developed a micro liquid-liquid extraction technique using 250 ul of pentane as solvent, and 900 ml of water. He obtained concentration factors of up to 10^5 . Dietz and Traud (32) used a classical extraction technique for the determination of volatile organohalides in water.

Identification of Trace Organics

Because of these tremendous analytical advances, a large amount of data has accumulated in the past five years on the levels of trace organics in waters. The work done by the United States Environmental Protection Agency on the New Orleans drinking water supply, (33) in which sixty-six organic compounds were identified, brought this research to the public's attention. Even before the New Orleans study, Novak et al (34) found at least fifteen compounds in finished drinking water, ranging in concentration between 0.1 and 60 ug/l. Included among these compounds were chloroform, trichloroethylene and dichloroethane. Rook (17) had also found these organohalides as well as carbon tetrachloride, tetrachloroethylene dichloroethane, chlorobenzene, hexachlorobutadiene, and alkylated aromatics in treated water from the Rhine River. Grob (18) identified fifty constituents out of hundreds of peaks representing trace contaminants in Zurich tap water, with an average concentration of 20 ng/l. Included in this list were dichloro and trichloro benzenes. Further work by the same author (21) increased the number of identified compounds to 136.

In 1974, Rook (35) found that the haloforms, chloroform, bromodichloromethane, chlorodibromomethane, and bromoform, were major contaminants of drinking water.

He also concluded that these haloforms were introduced during the water treatment process, and were not present in the raw water. This conclusion was supported by the work of Bellar (36) later during the same year.

In late 1974, the preliminary analytical report on the New Orleans water supply was released, listing 66 organic compounds which had been identified. These compounds included such known or suspected carcinogens as carbon tetrachloride, 2-chloroethyl ether, chloroisopropyl ether, chloroform, dieldrin, heptachloronorbornene, hexachlorobutadiene, hexachloroethane, trichloroethylene, and trichloroethane. The list of chemicals was later expanded to 86 compounds in the final report (37).

The New Orleans study was expanded to the so called "80 city survey" (38) and to date over 250 different organic chemicals have been identified in drinking waters around the United States.

HEALTH EFFECTS OF ORGANIC DRINKING WATER CONTAMINANTS

The recent concern over the health effects of organic chemicals in drinking water was prompted in part by the Environmental Defense Fund's report (39-41) that persons who drank water from the New Orleans drinking water supply ran a greater risk of contracting cancer than those drinking water from a relatively uncontaminated source. This report was widely reported by the news media, although the scientific community (42,43), questioned the validity of the statistical approach.

Further work by the EPA, National Institute of Occupational Health (NIOSH) and the National Cancer Institute (NCI), demonstrated that both chloroform (44,45) and trichloroethylene (46) were carcinogenic in large concentrations. Carbon tetrachloride, also found in the New Orleans supply has been known as a carcinogen for a long period of time (47).

A great deal of work has been carried out to determine the carcinogenicity potential of low levels of organic compounds in drinking waters. In 1947, Stocks demonstrated that the London population served by an underground water supply in Kent had a lower rate of cancer mortality than those served by polluted river source waters. Studies made in Holland showed that municipalities receiving their drinking water from a polluted source had a higher cancer death rate than those taking water from underground sources (48).

In the EPA Report to Congress (38) one epidemiological study indicated a statistically significant correlation between chloroform concentration in drinking water and cancer mortality for all anatomical sites. Using data from a different survey, no correlation between cancer mortality and chloroform concentration could be found.

Several authors have tried to determine whether extracts from drinking water were carcinogenic. In 1963 Heuper (49) found that the carbon chloroform (CCE) and carbon alcohol extracts (CAE) of raw and finished water from a polluted source were both highly carcinogenic to test animals indicating the presence of one or more carcinogens.

Tardiff and Deinzer (50) used both reverse osmosis and CAE and CCE extracts to concentrate organics for physiological studies. They found that all the extracts were very toxic in animal experiments. However, Maruoka et al (51) found that the carbon n-hexane extract from a CAM sampler, recovered from a drinking water, and administered to mice for one month, was not toxic.

Because chloroform is a known carcinogen, and because there is some doubt whether or not it can cause cancer at the levels present in finished drinking water, Tardiff (52) suggested that the maximum allowable level should be 70 ug/l, on the average. This level assumes a safety factor of 5,000 for an infant.

Benzene, and alkylbenzenes have not clearly been established to be carcinogenic in experimental animals, although epidemiological and clinical studies, largely of occupational exposures, suggest their possible carcinogenicity (38).

EXPERIMENTAL

Volatile Organohalides

The methods used in this investigation for the analysis of volatile organohalides have been discussed in detail in a report and in publications by Nicholson and Meresz (53,54,55).

Organochlorine Pesticides, Polychlorinated Biphenyls, and Triazine Herbicides

Water samples were taken directly in solvent pre-rinsed 0.57 l (20 oz) glass bottles with aluminum foil-lined caps. Samples were stored at 4° until analysed. All water samples were extracted unfiltered. Extraction was performed in the original containers by tumbling for 15 min. with 40, then 2 x 20 ml portions of pesticide grade methylene chloride. The combined extracts were dried over anhydrous sodium sulphate, rotary evaporated to 0.5 ml, then diluted with pesticide grade hexane to 2.0 ml prior to cleanup.

Cleanup was effected by chromatography on a 16 cm x 0.6 cm column of activated (130°C) Florisil (60-80 mesh). The column was packed using a hexane slurry of Florisil, the concentrated extract transferred with rinsing to the column, and the column eluted with the following solvents:

Fraction I, 15 ml of 25% methylene chloride in hexane (pesticide grade), eluted heptachlor, aldrin, α,γ -chlordanes, HCB, α,β,γ -BHC's Mirex, DDE, DDD, DDT, and PCBs, if present;

Fraction II, 15 ml of methylene chloride (pesticide grade) eluted heptachlor epoxide, endosulfan, dieldrin, endrin, if present;

Fraction III, 50 ml of diethyl ether (pesticide grade-alcohol free) eluted the triazine herbicides.

The eluted fractions were evaporated gently to approximately 0.2 ml under a dry air stream, then evaporated using hand heat to near dryness and made up to 1.0 ml with hexane prior to gas chromatographic analysis.

Fractions I, II: Analysis was carried out on a Varian 1400 gas chromatograph fitted with a ^{63}Ni detector, 1.8 m x 2 mm I.D. pyrex column containing an 11% (OV-17/QF-1) mixed phase packing. The oven was heated to 215° , the injector 225° , and the detector 300° . The carrier gas used was nitrogen at a flow rate of 40 ml/min.

Any Fraction I containing PCBs and/or pesticides was subjected to additional chromatography using a 20 cm x 0.6 cm column of 100-200 mesh Florisil. The column was dry packed after cooling the Florisil for 10 min. After transfer of the fraction to the column, elution was carried out as follows:

Fraction Ia, 20 ml of benzene-free hexane (pesticide grade) eluted HCB, heptachlor, Aldrin, DDE, Mirex and PCBs;

Fraction Ib, 15 ml of 25% methylene chloride in hexane (pesticide grade) eluted DDD, DDT α, γ -Chlordanes, α, β, γ -BHC.

Analyses were performed as for Fractions I, II. Confirmation for pesticides in Fractions I, II, were carried out on a 10% DC 200 column, on a Varian 1400 gc with ^{63}Ni detector.

Fraction III: Analysis was carried out on a Varian 1400 chromatograph fitted with an alkali flame detector timed for optimum nitrogen selectivity, using a 1.8 m x 2 mm I.D. pyrex column containing 6% Carbowax 20M on Gaschrom G conditioned for 2 days at 260°C . The oven temperature was programmed from $200-250^{\circ}$ at $2^{\circ}/\text{min}$, the injector and detector were maintained at 230° and 260° respectively. The carrier gas used was helium at a flow rate of 35 ml/min.

Confirmation of Triazine herbicides was carried out on a Tracor 222 Chromatograph, 1.8 m x 2 mm I.D. Dexsil 410 column fitted with a Hall electrolytic conductivity detector in the nitrogen mode.

Gas Chromatography/Mass Spectrometry

The computerized gas chromatograph/mass spectrometer system consisted of a Data General Nova II computer, a Hewlett-Packard 7640 gas chromatograph and an Associated Electronics Industries MS-30 mass spectrometer.

The 500 ml capacity glass sparging device, used for stripping volatile organics from water samples, had a medium glass frit at the bottom. Water samples (500 ml) were placed in this reservoir and heated at 90° in a water bath. With nitrogen flowing through the sparging device at 30 ml/min, the volatile organics were collected at ambient temperature on a trap.

The trap consisted of 30 cm x 4.9 mm I.D. stainless steel tubing, 15 cm of which was packed with 3% Dexsil 300 on Chromosorb W and the other 15 cm with Tenax GC. The samples were sparged for 45 min to 1 hour.

The trap was then connected inside a gas chromatographic oven to the column via a four-port valve. By switching the valve, gas flow was reversed through the trap, and onto the column. The 1.8 m x 2.2 mm I.D. glass column was packed with 3% UCW-98 on Chromosorb W 60/80 mesh. The flame ionization detector was operated at 300°. The oven was programmed from 60° to 200° at 10°/min.

During the analysis, the computerized gc/ms system acquired a complete mass spectrum every 5 seconds. Identification was confirmed by comparison of the spectra obtained with the spectra of standards.

RESULTS AND DISCUSSION

A complete analysis of any one drinking water for all the volatile and non-volatile organic compounds that may be present would be an extremely slow and tedious process. It was, therefore, decided to concentrate on determining those compounds that have been found previously in drinking water and are either suspected, or known to be toxic. Thus both "Free" (24), and "Total Potential" (54) haloforms were determined at 48 different water treatment plants throughout the Province. Pesticide, herbicide, and polychlorinated biphenyl levels were determined in both raw and treated drinking water at twenty-seven locations. A general scan for volatile organics was carried out using gas chromatography/mass spectrometry on water from fourteen sites. Detailed studies of the levels of organics throughout both the Brantford and Cayuga water treatment plants were done to determine the effect of water treatment on levels of the organic compounds found, and to establish the source of the contamination.

Volatile Organohalides

At the beginning of the survey for volatile organohalides in Ontario drinking water plants in late 1974, the direct aqueous injection method (DAI) was used for the determination of chloroform, bromodichloromethane, and chlorodibromomethane. Two unidentified peaks appeared from time to time in some samples. These were later identified by gc/ms as carbon tetrachloride and ethylene chloride and were quantitated on a routine basis starting in 1976.

The DAI method can be used to determine bromoform and tetrachloroethane as well as the compounds listed above, but a separate injection must be made, and the column temperature must be raised by 20°C (54). Initially, samples were analysed at both temperatures, but since neither of these compounds were found, subsequent samples were analysed only for those compounds which could be determined at the lower column oven temperature.

(a) Correlation of the Direct Aqueous Injection (DAI) and Gas Sparging (GS) Methods

Because the DAI method was newly developed, it was considered essential that the results obtained were comparable to those given by the published gas sparging method of Bellar (24). The comparison of the results led to the discovery (54) that the two methods did not produce the same values for the concentrations of chloroform and bromodichloromethane when the same sample was analysed by both methods on the same day. It was shown that during the DAI analysis, precursors of the haloforms decomposed to produce chloroform, bromodichloromethane, and chlorodibromomethane. The results obtained by this method were thus characterized as the total potential chloroform, bromodichloromethane and chlorodibromomethane concentrations. The Bellar method produced a result which was classified as the free haloform concentration. Correlations have been discussed elsewhere, (53), but the data plotted in Figures 1 to 3 include all data obtained to date.

FIGURE 1

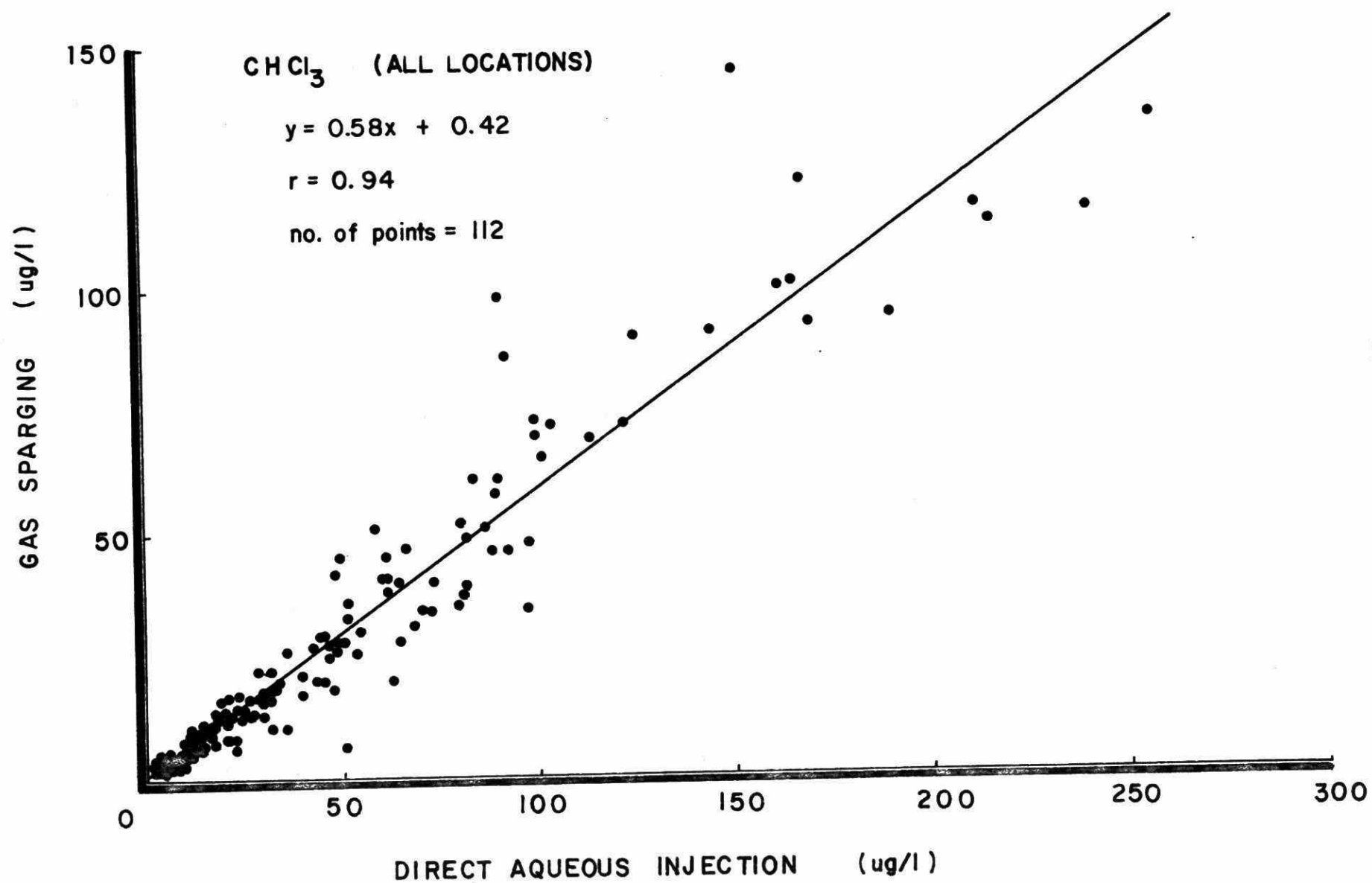


FIGURE 2

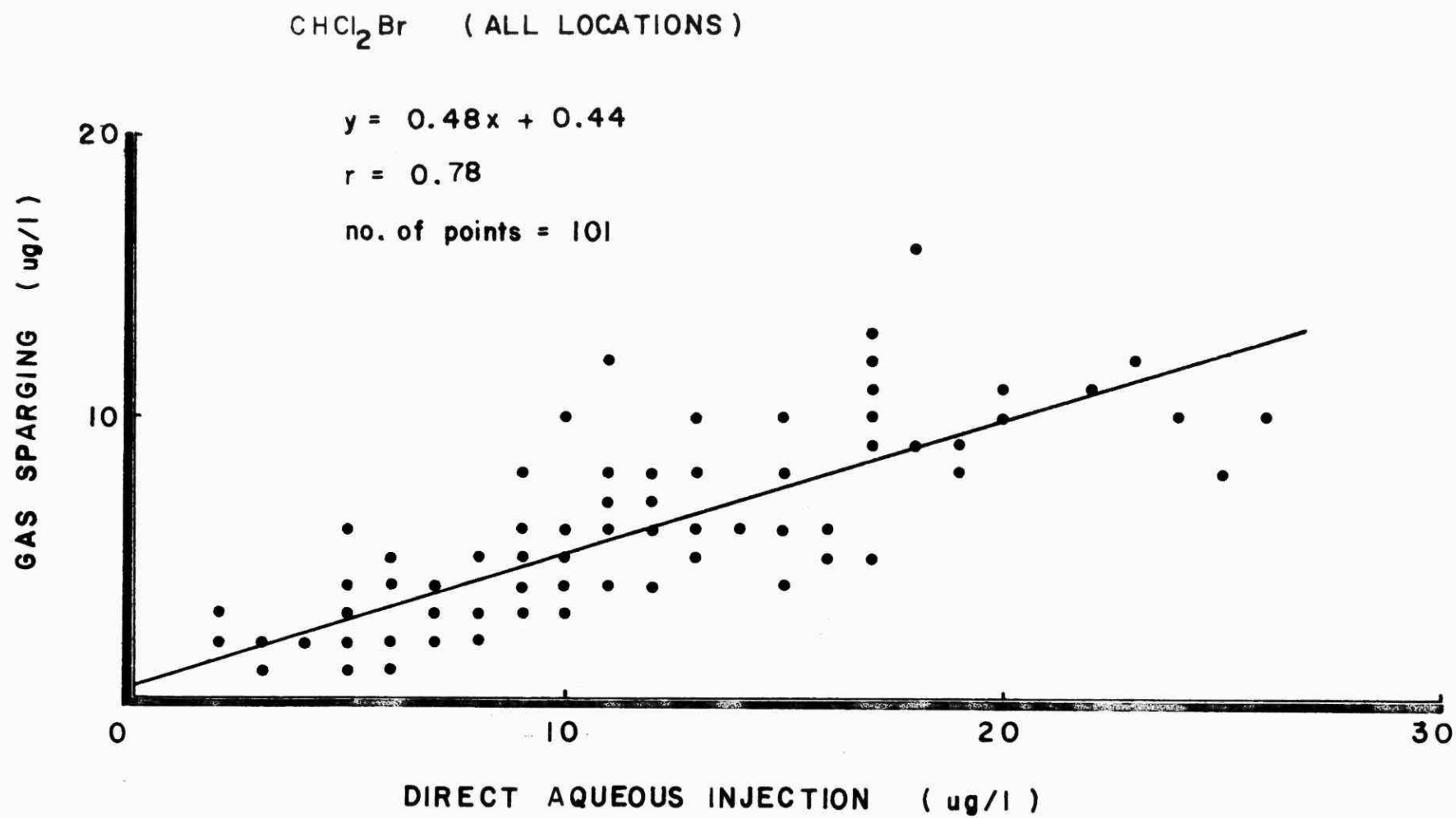
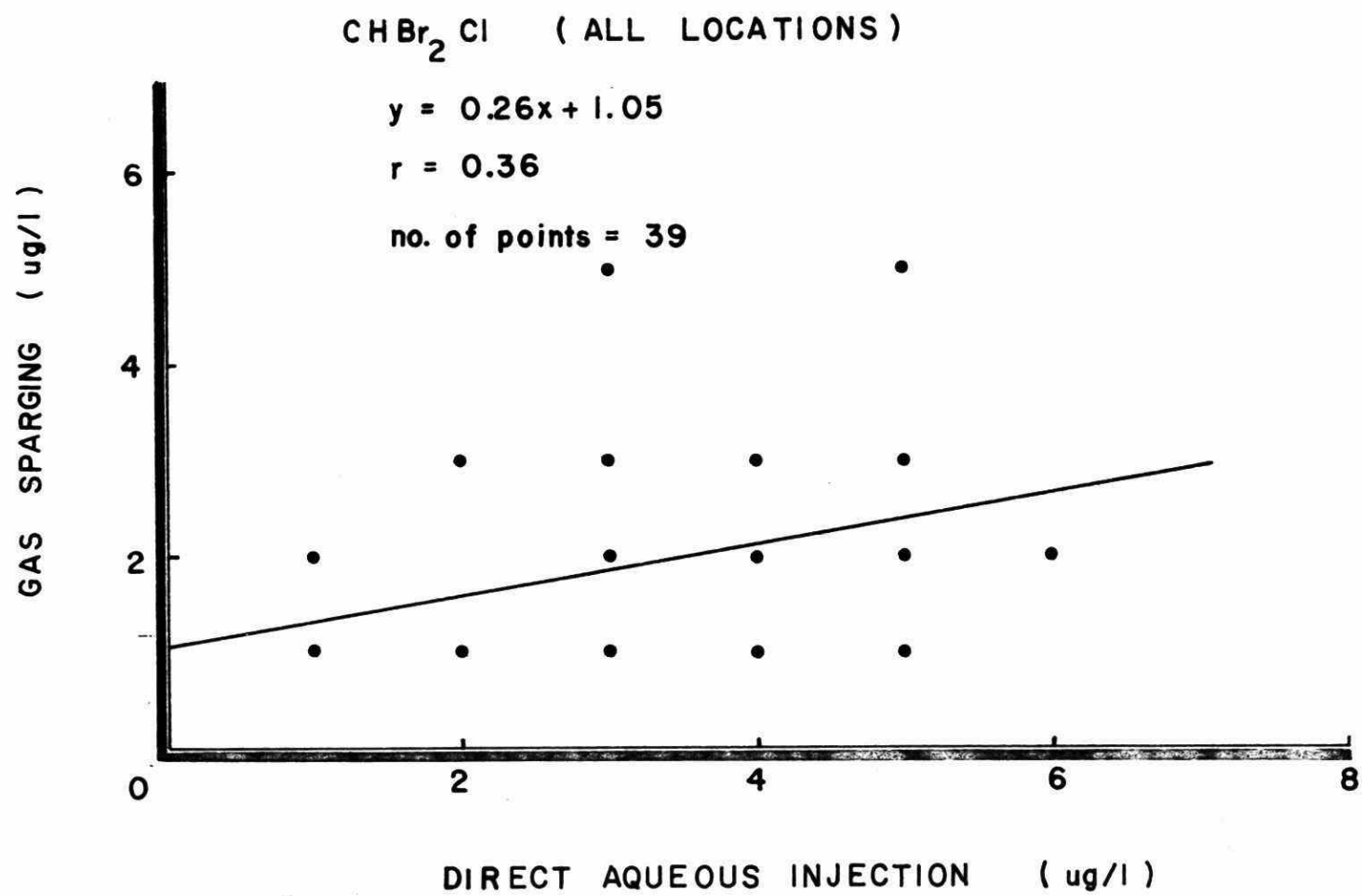


FIGURE 3



The correlation coefficient for chloroform at 0.94 is quite acceptable, but the correlation coefficients for bromodichloromethane at 0.78, and that for chlorodibromomethane at 0.36 are poor, which may reflect the fact that most of the values obtained are at, or near the detection limits for both methods, as shown in Table I.

TABLE I

DETECTION LIMIT FOR SELECTED ORGANOHALIDES

<u>Compound</u>	<u>Direct Aqueous Injection</u> <u>Detection Limit (ug/l)*</u>	<u>Gas Sparging</u> <u>Detection Limit</u> <u>(ug/l)*</u>
Chloroform	1.0	0.1
Carbon tetrachloride	0.1	10.0
Trichloroethylene	2.0	0.3
Bromodichloromethane	0.5	0.5
Chlorodibromomethane	1.0	2.0

* Detection Limit: 2 x noise level

The DAI method is much faster than the GS technique, allowing the analysis of up to ten times as many samples per day as the latter. Initially, samples were analysed by both methods, and it was hoped that a constant ratio between the values given by the two methods would be found. On the average, as has been mentioned previously, the ratio does remain fairly steady, but there is a wide variation in the actual values within each location. This variation must mean that the total potential haloform content must depend on factors such as organic loading, water temperature, chlorine dose, and residence time in the plant.

(b) Average Concentrations of Volatile Organohalides at 48 Locations.

Listed in Table II are the average concentrations of the five volatile organohalides obtained at each of the locations sampled so far. Belleville, Brantford, Cayuga, Dresden, Sudbury and Trenton, all had average total potential haloform values in excess of 100 ug/l. All of these locations have rivers or small lakes as their raw water source. Indication of carbon tetrachloride and trichloroethylene being present was found at a number of locations. However, with the exception of Sombra and Lambton, the levels detected were too low to allow confirmation of identity by gc/ms.

(c) Average Concentrations of Volatile Organohalides from Various Raw Water Sources.

Table III lists the average levels obtained from each type of water source tested: rivers, lakes, the Great Lakes system, and well water supplies.

TABLE II

AVERAGE VOLATILE ORGANOHALIDE CONCENTRATION IN ug/l

BY DAI AT 48 LOCATIONS

LOCATION*	NUMBER OF DETERMINATIONS	CHCl ₃ Conc., (σ%) †	CCl ₄ Conc., (σ%)	C ₂ HCl ₃ Conc., (σ%)	CHCl ₂ Br Conc., (σ%)	CHBr ₂ Cl Conc., (σ%)
Acton (W)	1	1	nd	nd	nd	nd
Amherstburg (GL-E)	8	60, (37)	nd	nd	19, (29)	3, (77)
Belleville (R)	12	140, (41)	T §	T	13, (32)	nd
Blenheim (GL-E)	8	28, (29)	T	nd	9, (30)	2, (31)
Bowmanville (GL-O)	9	27, (66)	T	T	12, (34)	4, (59)
Brantford (R)	31	159, (30)	T	T	22, (55)	T
Burlington (GL-O)	5	19, (60)	T	nd	9, (13)	4, (0)
Cayuga (R)	25	117, (53)	T	T	20, (50)	nd
Chatham (R)	5	23, (54)	nd	nd	12, (64)	4, (55)
Dresden (R)	3	111, (27)	nd	nd	13, (39)	T
Elgin (GL-H)	11	47, (29)	T	nd	14, (58)	5, (44)
Georgetown (W)	1	6	nd	nd	nd	nd
Goderich (GL-H)	8	44, (48)	T	nd	9, (59)	3, (165)
Grand Bend (GL-H)	6	27, (35)	T	T	8, (43)	3, (45)
Guelph (W)	1	nd	nd	nd	nd	nd
Halton (W)	1	11	0.7	nd	8	3

* Raw water sources

GL - Great Lakes System

S - Superior

H - Huron

E - Erie

O - Ontario

R - River

W - Well

L - Lake

† - σ% Relative standard deviation

nd - not detected

§ - T Trace

-22-

LOCATION	NUMBER OF DETERMINATIONS	CHCl ₃ Conc., (σ%)	CCl ₄ Conc., (σ%)	C ₂ HCl ₃ Conc., (σ%)	CHCl ₂ Br Conc., (σ%)	CHBr ₂ Cl Conc., (σ%)
Harrow- Colchester (GL-E)	12	75, (34)	.5, (147)	3, (170)	17, (36)	4, (44)
Hawkesbury (R)	2	43, (25)	nd	2	2	nd
Kingston (GL-O)	5	37, (34)	.2, (117)	T	14, (20)	4, (61)
Markham (W)						
Don Mills WTP	2	3	nd	nd	5	13
John St. WTP	1	36	nd	nd	41	38
Napanee (R)	6	74, (58)	.4, (175)	nd	9, (35)	nd
Newcastle (GL-O)	2	20	3	T	13	6
Niagara-on-the-Lake (GL-O)	2	28	nd	nd	16	4
Oakville (GL-O)	6	18, (26)	.3, (217)	T	11, (14)	5, (13)
Ottawa (R)						
Britannia WTP	3	55, (143)	.3, (173)	nd	nd	nd
Lemieux WTP	2	56, (126)	nd	nd	2, (141)	nd
Pembroke (R)	4	65, (45)	nd	nd	1, (141)	nd
Port Lambton (GL-H)	8	23, (52)	T	nd	8, (36)	3, (31)
Prescott, (GL-O)	3	25, (34)		nd	8, (130)	1
Renfrew (R)	3	52, (42)	nd	nd	1	nd
Sarnia (GL-H)	2	38	6	nd	9	5
Sault Ste. Marie (GL-S)	3	11, (9)	nd	nd	nd	nd

LOCATION	NUMBER OF DETERMINATIONS	CHCl ₃ Conc., (σ%)	CCl ₄ Conc., (σ%)	C ₂ HCl ₃ Conc., (σ%)	CHCl ₂ Br Conc., (σ%)	CHBr ₂ Cl Conc., (σ%)
Smith Falls (R)	7	42, (24)	.5, (90)	nd	2, (74)	nd
Sombra (GL-H)	2	38	6	nd	9	5
Southampton (GL-H)	3	47, (40)	.7, (166)	nd	11, (19)	3, (65)
Sudbury						
Coniston WTP (L)	5	116, (33)	.8, (202)	nd	5, (64)	nd
Lake Ramsey WTP (L)	5	42, (29)	.3, (171)	nd	6, (79)	2, (79)
Thunder Bay						
Bare Pt. (GL-S)	17	33, (30)	T	nd	7, (76)	T
Loch Lomond WTP (R)	2	76	nd	nd	17	18
Toronto (GL-O)						
Lakeview WTP	5	6, (42)	nd	nd	6, (46)	1
R. C. Harris WTP	8	8, (76)	T	T	5, (97)	2, (83)
Westerly WTP	5	8, (25)	T	T	5, (14)	4, (113)
Trenton (R)	13	145, (26)	T	T	9, (38)	T
Union (GL-E)	9	41, (45)	T	nd	14, (31)	3, (46)
Whitchurch-						
Stouffville (W)	1	60	nd	nd	8	4
Windsor (GL-H)	9	38, (46)	T	nd	14, (54)	3, (84)

The average chloroform content is related to the organic loading in each of the raw water sources. Appendix I lists the raw data from which the averages in Table II and III were obtained, and Appendix II lists the raw water sources. Listed as well in the Appendices are the haloform levels in the raw waters. The fact that these concentrations are always very low or below our detection limit supports the conclusions of other workers in the field that the haloforms are produced in the plant. Chloroform in the raw water in isolated samples at Blenheim, Bowmanville, Dresden, Grand Bend, Haileybury, Prescott, Southampton, Thunder Bay and Toronto (R.C. Harris WTP) could be due to either sample contamination, or collection of the raw water sample after prechlorination.

TABLE III

AVERAGE TOTAL HALOFORM CONCENTRATIONS
FOR VARIOUS RAW WATER SOURCES

<u>Source</u>	<u>CHCl₃ Concentration (ug/l)</u>			<u>CHCl₂Br Concentration (ug/l)</u>		
	<u>Average</u>	<u>Low</u>	<u>High</u>	<u>Average</u>	<u>Low</u>	<u>High</u>
n = no. sites						
Rivers						
(n = 14)	82	23	159	9	nd	22
Lakes *						
(n = 2)	79	42	116	55	4	7
Great Lakes System						
(n = 23)	31	6	75	10	nd	19
Wells						
(n = 7)	17	nd	60	8.9	nd	41

* 2 locations in Sudbury.

Listed in Table IV is the average chloroform and bromodichloromethane concentration by DAI for the individual Great Lakes.

TABLE IV
AVERAGE TOTAL HALOFORM CONCENTRATIONS
FOR FINISHED WATER
WITH GREAT LAKES SOURCES

<u>Great Lakes</u>	<u>No. of Sites</u>	<u>CHCl₃ Average Concentration ug/l, (σ%)*</u>	<u>CHCl₂Br Average Concentration ug/l, (σ%)</u>
Superior	2	22, (71)	3.5, (141)
Huron	8	36, (29)	10, (26)
Erie	4	51, (41)	15, (29)
Ontario	9	20, (51)	10, (39)

* Relative standard deviation

(d) Seasonal Variations in the Concentration of Organohalides

There is a general trend towards low haloform concentration during the winter, and higher values in the spring, summer and fall. This is illustrated in Figures 4 and 5 which are bar graphs showing the seasonal variation in the concentration of chloroform at Belleville and Brantford, respectively, for which a nearly complete set of data was available.

FIGURE 4

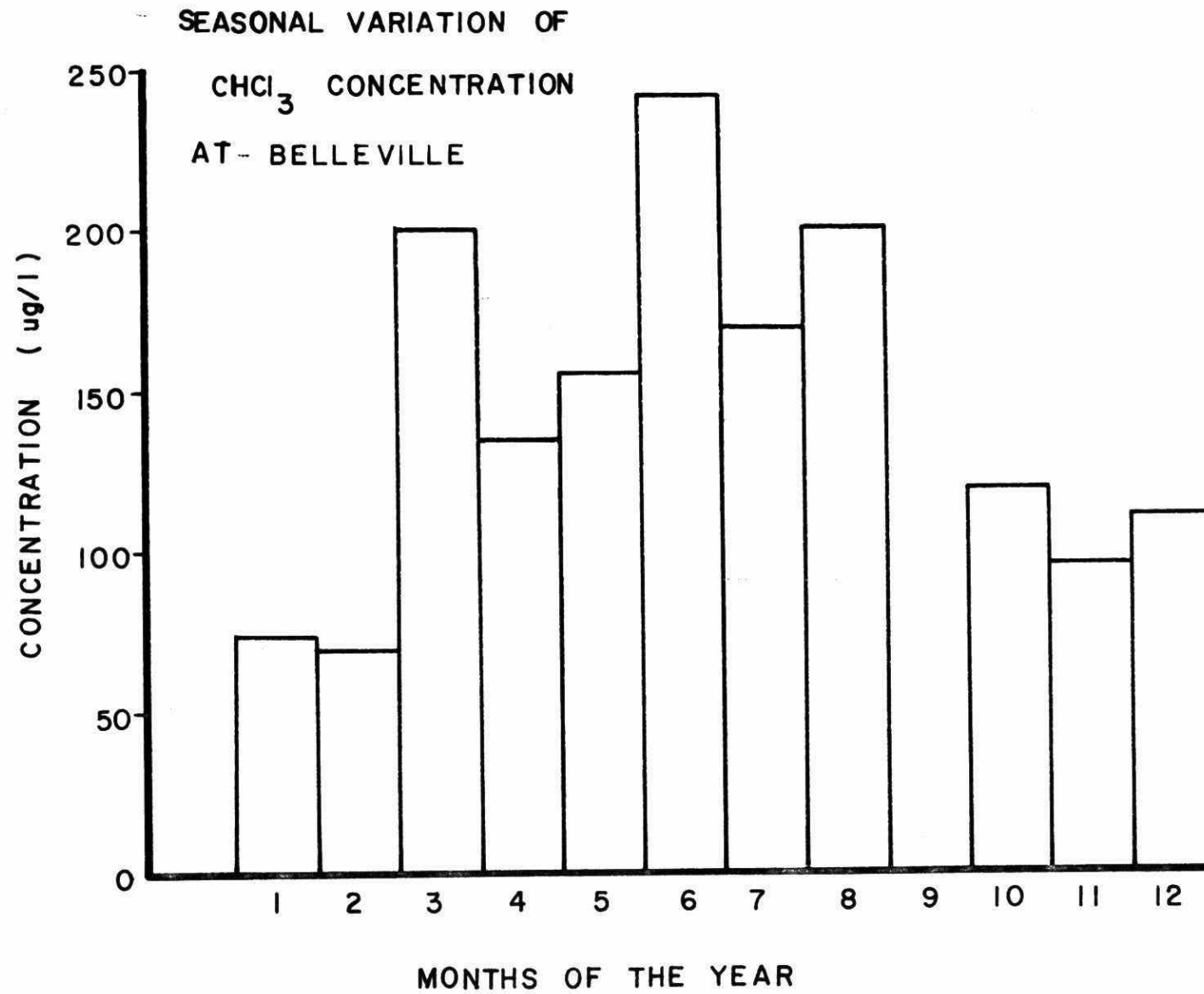
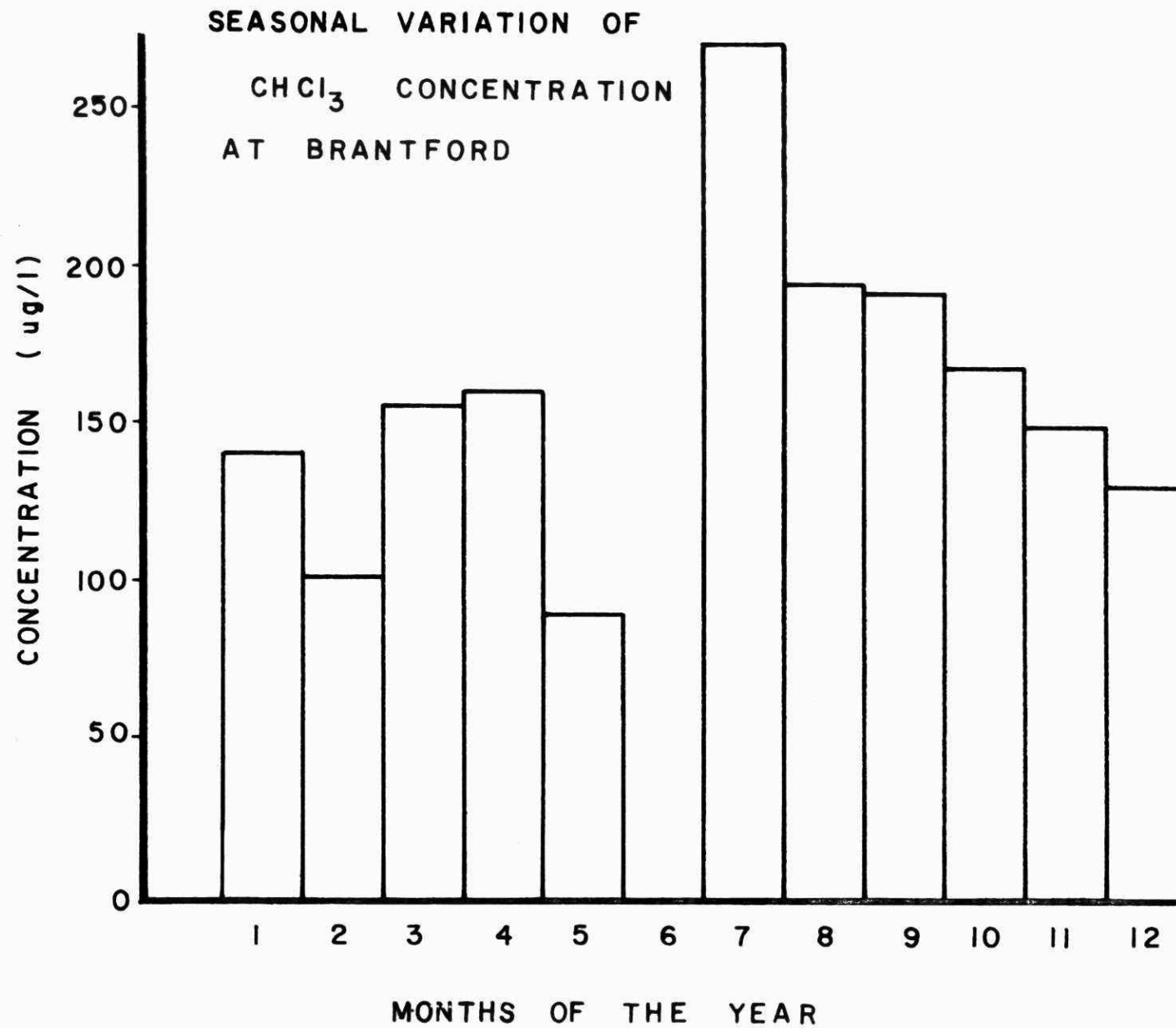


FIGURE 5



For Belleville and Harrow-Colchester, there is good correlation between temperature of the raw water, and the chloroform concentration (Table V). For Belleville, there is also good correlation between chloroform concentration and turbidity, colour, and chlorine dose.

TABLE V

CORRELATION COEFFICIENTS FOR
CHLOROFORM CONCENTRATION (DAI) WITH
TEMPERATURE, TURBIDITY, COLOUR, CHLORINE DOSE

<u>Location</u>	<u>Temperature</u>	<u>Turbidity</u>	<u>Colour</u>	<u>Cl₂ Dose</u>
Belleville	.91	.72	.94	.78
Harrow-Colchester	.95	NSC*	NA†	NA
Brantford	.54	NSC	NA	NSC
Thunder Bay (Bare Pt.)	NSC	NSC	NA	NA

* NSC no significant correlation

† NA data not available

Temperature of the raw water is perhaps the single most important factor influencing seasonal variation of haloform concentration. This holds true for Great Lakes (Harrow-Colchester) and river (Belleville, Brantford) raw water sources.

The fact that there is no seasonal variations at Thunder Bay probably reflects the fact that there is little change in the water quality of Lake Superior throughout the year.

Other factors, such as haloform precursor concentration, would certainly have some additional effect. In Figure 4, the high chloroform concentration in March may be due in part to additional haloform precursor present in the spring run-off.

Experimentally, increased pH has been shown to have a marked effect increasing haloform production (56). However, in the water treatment plants surveyed there is very little variation in the pH of the raw water throughout the year, so pH is not a seasonal factor.

No correlation with TOC could be obtained, although the U.S. - EPA (38) obtained a correlation with nonvolatile TOC.

(e) Haloform Concentrations at Various Stages of Water Treatment.

The data presented in Appendix I only details the concentration of the organohalides in raw and corresponding finished water. Several studies were done on the change in haloform levels throughout certain water treatment plants. The results from five locations are listed in Table VI. In general, the concentration of chloroform and bromodichloromethane seems to decrease during the various stages of water treatment. The concentration of the other volatile organohalides are too low to accurately determine trends.

TABLE VI

CHANGES IN VOLATILE ORGANOHALIDE CONCENTRATION
THROUGHOUT FIVE WATER TREATMENT PLANTS

<u>Location</u>	Organohalide Concentration (ug/l)				
	<u>CHCl₃</u>	<u>CCl₄</u>	<u>C₂HCl₃</u>	<u>CHCl₂Br</u>	<u>CHBr₂Cl</u>
<u>BELLEVILLE</u>	<u>16/7/76</u>				
Raw	nd	nd	nd	nd	nd
Flash Mix	189	0.5	nd	13	nd
Before Filter	196	nd	nd	15	nd
Plant Effluent	153	nd	nd	15	nd
Distribution System	147	nd	nd	nd	nd
<u>BRANTFORD</u>	<u>3/9/75</u>				
Raw	nd	nd	nd	nd	nd
After Prechlorination	314	nd	nd	45	nd
Flash Mix	322	nd	nd	40	nd
Before Filter	338	nd	nd	43	nd
Plant Effluent	256	nd	nd	35	nd
	<u>16/2/76</u>				
Raw	nd	nd	nd	nd	nd
After Prechlorination	113	nd	nd	18	2
Flash Mix	100	nd	nd	16	2
Before Filter	89	nd	nd	16	2
After Filter	89	nd	nd	14	2
Plant Effluent	73	nd	nd	11	2

Organohalide Concentration (ug/l)

Location	CHCl_3	CCl_4	C_2HCl_3	CHCl_2Br	CHBr_2Cl
----------	-----------------	----------------	--------------------------	--------------------------	--------------------------

CAYUGA 8/6/76

Raw	nd	nd	nd	nd	nd
Flash Mix	8	nd	nd	nd	nd
Settling Basin	73	3.6	12	17	2
Before Filter	82	3.2	10	20	2
After Filter	50	0.4		15	2

16/6/76

Raw	4	nd	nd	nd	nd
Flash Mix	nd	nd	nd	nd	nd
Settling Tank	166	2.2	9	36	3
Before Filter	155	3.1	10	32	3
Plant Effluent	147	2.2	10	29	3

HAWKESBURY 2/1/75

Raw	nd	nd	nd	nd	nd
Before Filter	37	nd	nd	2	nd
Plant Effluent	51	nd	nd	4	nd
Distribution System (1 mile from plant)	47	nd	nd	3	nd

TORONTO-LAKEVIEW

15/1/75

Raw	nd	nd	nd	nd	nd
Before Filter	15	nd	nd	4	nd
Taste Control	8	nd	nd	7	5
Plant Effluent	6	nd	nd	9	nd

(f) Water Treatment Plant Sampling Locations, and
Preservation of Samples

It was found that the chloroform levels at different stages in the treatment process, other than the raw and treated waters, do not accurately reflect the levels present at the time of sampling.

Samples of water were taken at the Brantford water treatment plant in early June of 1976. Half of the samples were preserved at the site with sodium thiosulphate. All of the samples were kept at ambient temperature and rushed to the laboratory for analysis by DAI and GS. Both the DAI and GS methods showed a dramatic increase in the chloroform concentration in the unpreserved samples from the prechlorination chamber as shown in Figure 6. A rapid initial increase in the chloroform level was observed in the finished water, using DAI, but this flattened out within three hours. In Figure 6, the chloroform level (as determined by DAI) in the water from the prechlorination chamber is much higher than that determined by the same method, in the finished water.

The opposite is true in the samples preserved with sodium thiosulphate, as shown in Figure 7. The finished water chloroform levels in both the preserved and unpreserved samples (by DAI) are identical. These results indicate that the chlorine in the sample keeps on reacting with the haloform precursors over a twenty-four hour period. This reaction is stopped by addition of the sodium thiosulphate.

FIGURE 6

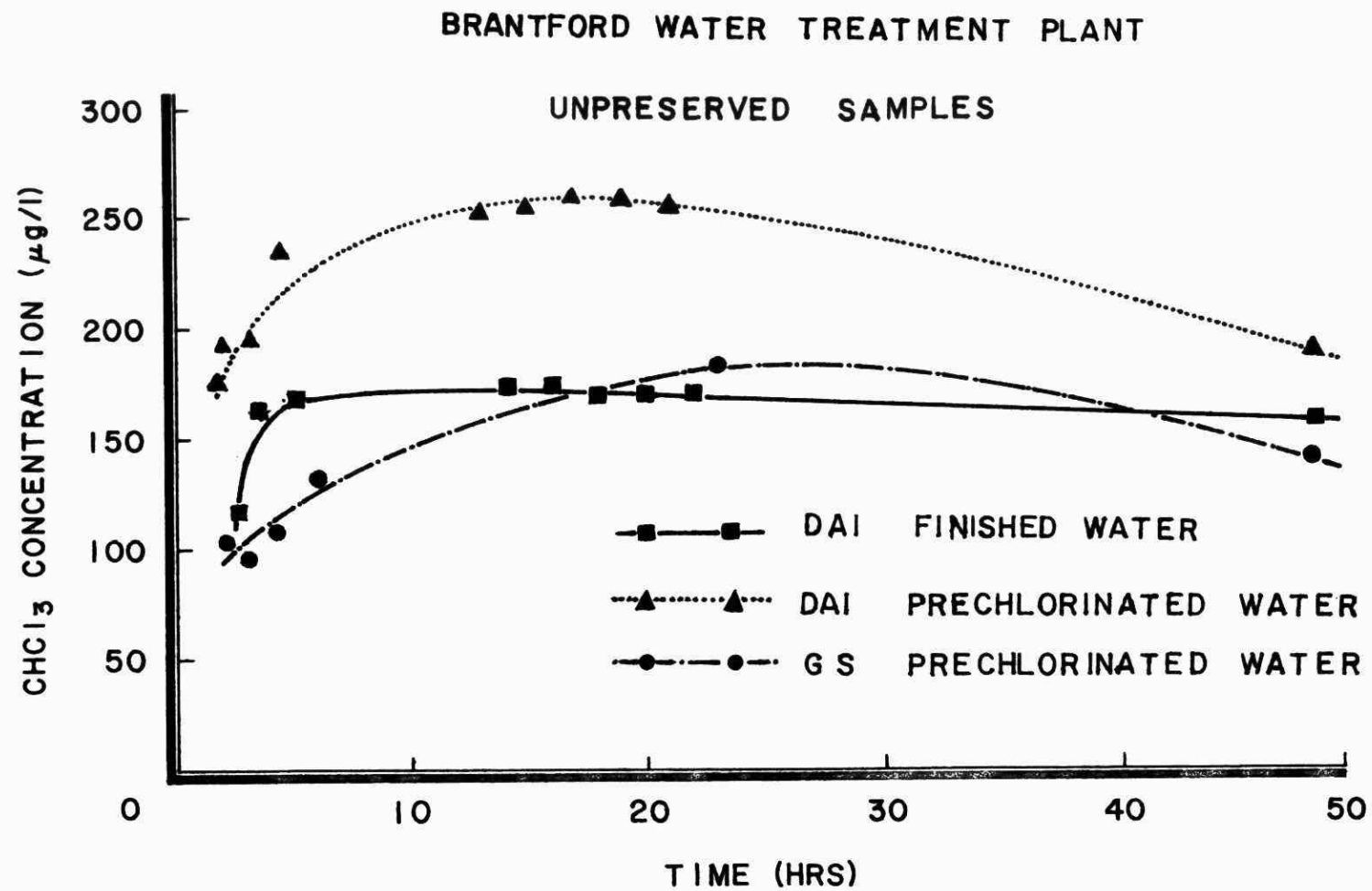
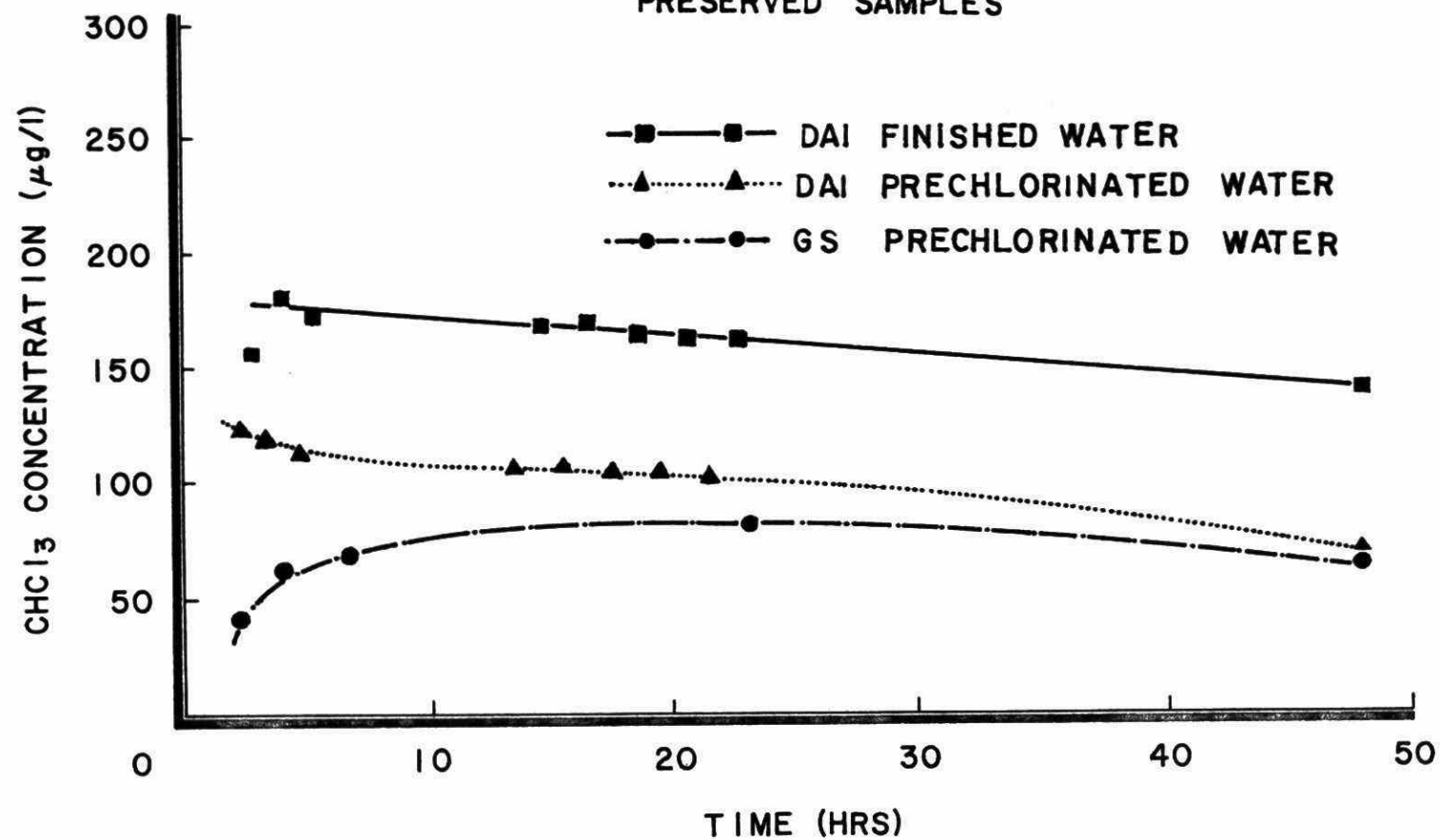


FIGURE 7

BRANTFORD WATER TREATMENT PLANT

PRESERVED SAMPLES



There is an interesting occurrence in the preserved sample from the prechlorination chamber, in that the chloroform level keeps increasing, according to the GS method. This indicates that the chlorinated precursors still undergo the haloform reaction in the absence of chlorine. However, there is no change in this sample according to the DAI method, indicating that the decomposition of intermediates is completed during analysis by this method.

The fact that no increase in the chloroform concentration occurs in the unpreserved sample of treated water, indicates that the precursors for the formation of the haloforms have been removed or completely chlorinated during the treatment process.

The conclusion that can be drawn from these results is that any analysis of samples taken after prechlorination and before filtering will not give relevant results. Also, present treatment at the Brantford Water Treatment Plant does not significantly effect the level of haloforms.

(g) Sources of Contamination

That chloroform is produced by the water treatment process is now well established (35,36). It has further been shown by Stevens (56) and Rook (57) that the nonvolatile humic and fulvic acids in drinking water are the most probable precursors of chloroform.

The formation of the mixed haloforms, bromodichloromethane, and chlorodibromomethane, is more of a mystery.

Bunn et al (60) have shown that addition of bromide ion to raw water causes an increase in the mixed haloforms upon chlorination. Although he strongly suspected that the bromide ion plays an important role in the formation of these compounds, Rook (35) could not explain the fact that while the ratio of chlorine to bromine in the haloforms is 5.5 to 1, the ratio of HOCl to bromide ion is 125 to 1.

Pesticides, Herbicides and Polychlorinated Biphenyls

The detection limits for the pesticides, herbicides and PCBs determined at 27 locations around Ontario are listed in Table VII.

TABLE VII

DETECTION LIMIT FOR PESTICIDES, HERBICIDES AND
POLYCHLORINATED BIPHENYLS

	<u>ng/l</u>		<u>ng/l</u>
(a) <u>PCB</u>	10	(c) <u>HERBICIDES</u>	
(b) <u>PESTICIDES</u>		Prometone	50
HCB	1.0	Propazine	50
α -BHC	1.0	Atrazine	50
Lindane	1.0	Prometryne	100
β -BHC	1.0	Simazine	50
Heptachlor	1.0	Ametryne	100
Aldrin	1.0	Secor	100
Heptachlor Epoxide	1.0	Bladex	100
Thiodan I)	1.0		
Thiodan II) Endosulfan	1.0		
p,p,-DDE	1.0		
Dieldrin	1.0		
Endrin	1.0		
o,p,-DDT	5.0		
p,p,-DDD	5.0		
p,p,-DDT	5.0		
α -chlordan	1.0		
γ -chlordan	1.0		
Mirex	5.0		

TABLE VIII

LOCATIONS WHERE BIOCIDES WERE
FOUND IN TREATED WATER

<u>Location</u>	<u>Biocide* (ug/l)</u>
Amherstburg	Atrazine (0.05)
Brantford	Atrazine (.42), Simazine (.06) Dieldrin (trace)
Cayuga	Atrazine (.45), Simazine (.05) Dieldrin (trace)
Dresden	Atrazine (.4)
Goderich	Atrazine (.07)
Guelph	Atrazine (trace)
Niagara-on-the-Lake	Atrazine (.05), Lindane (.02), α -BHC (.01), β -BHC (.001)
Pembroke	Atrazine (trace)
Toronto (Lakeview)	Atrazine (trace)

* The highest concentration found is reported and expressed in ug/l (ppb).

(trace) - below detection limit.

In no case were the levels for atrazine above the 0.45 ug/l level in treated water. In the case of dieldrin, lindane, and BHC, the levels found were very close to the limits of detection for the method. Because of the very small quantities found, confirmation by gc/ms was impossible. The data from the survey is listed in Appendix III.

(a) Sources of Contamination

Reasons for the occurrence of atrazine in the finished water at Brantford, Cayuga and Dresden are that these municipalities draw their raw water from rivers that flow through the most productive corn belt in Ontario. Atrazine has its primary use as a herbicide on corn fields. Also, the samples were taken during the height of the run-off, when biocides in the raw water sources would be at their maximum. The highest concentration of atrazine reported in finished water by the EPA (38) is 5.4 ug/l. This value is 12 times greater than the highest concentration found in Ontario.

As can be seen from Appendix III, there is no significant reduction in the level of atrazine during water treatment.

From an extensive survey of the drinking water of U.S. cities (59) in 1975, atrazine was the second most widely occurring compound. The most widely occurring impurities, in order of frequency of occurrence are diethylphthalate, atrazine, naphthalene, dibutyl phthalate, diisobutyl phthalate, butyl octyl maleate, methyl benzoate, methylnaphthalene and di(2-ethylhexyl)-phthalate.

Gas Chromatography/Mass Spectrometry

The gc/ms system was used to confirm the presence of the organohalides at different locations. The results are listed in Appendix IV. During the study, several organic compounds in trace concentrations were identified in a number of drinking water supplies. The locations and the compounds found are listed in Table IX. Haloforms are excluded from this list.

TABLE IX

ORGANICS APART FROM HALOFORMS IDENTIFIED

IN DRINKING WATER SUPPLIES

<u>Location</u>	<u>Found</u>
Brantford	Benzene, Toluene, Ethylbenzene, Xylenes, Ethyltoluene, Diethylbenzene, Hexane.
Cayuga	Benzene, Toluene, Xylenes, Ethylbenzene, Cymene, Ethyltoluenes, Diethylbenzenes.
Goderich	Dichlorobenzene
Ottawa	Benzene, Toluene
Port Lambton	Methylene chloride, Tetrachloroethane, Xylenes
Smiths Falls	Benzene, Toluene, Hexane
Union	Toluene, Ethylbenzene, Cumene

Further studies were carried out at the Brantford and Cayuga Water Treatment Plants. In both cases no aromatics were found in the raw water, yet the finished water contained aromatic hydrocarbons. Of the two sites, Cayuga displayed a five times higher concentration and was chosen for further studies.

Benzene and several alkylbenzenes in Cayuga's finished water were quantitated at the ng/l (parts per trillion) level. These results are given in Table X.

TABLE X

AROMATIC HYDROCARBONS IDENTIFIED

AT CAYUGA WTP

<u>Compound</u>	<u>Raw Water</u>	<u>Finished Water (ng/l)</u>
Benzene	nd	402
Toluene	nd	280
Ethylbenzene and/or <u>p</u> and <u>m</u> -xylene	nd	137
<u>o</u> -xylene	nd	46
Ethyltoluenes	nd	60
Diethylbenzenes	nd	16

nd = none detected at 15 ng/l detection limit.

At Cayuga, no in-plant source of the aromatic hydrocarbons was found, nor did the analysis of the chemicals used during water treatment reveal any significant amount of the aromatics. The fresh filter medium, anthracite, was found to contain trace amount (parts per trillion) of toluene. However, an aliquot of used filter medium showed benzene and alkylbenzenes in concentrations nearly two orders of magnitude higher than the concentrations found in the finished water.

(a) Sources of Contamination

The alkylated benzenes could be coming from "BTX" (benzene, toluene, xylene), a relatively common industrial solvent mixture.

It is possible that "BTX" or some industrial solvent is being discharged into the Grand River from which Brantford and Cayuga draw their water. Occasional relatively high concentrations of aromatic hydrocarbons in the raw water could enter the water treatment plant to be adsorbed by the anthracite coal filter medium and then desorb into the finished water over an extended period of time.

Studies in the laboratory have demonstrated these adsorptive properties of the anthracite filter medium (60). When water containing parts per million of the aromatics was introduced onto a column of the anthracite, aliquots of subsequent washes showed the persistence of the aromatics in the elute at the parts per trillion level.

APPENDIX I

FREE AND TOTAL POTENTIAL VOLATILE ORGANOHALIDE

CONCENTRATIONS IN FINISHED DRINKING WATER

ALL CONCENTRATION ARE EXPRESSED IN ug/l

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Acton	23/1/76	1	nd	nd	nd	1						nd
Amherstburgh	18/12/74	46			26	5						nd
	9/3/75	45			24	5						nd
	12/8/75	54			23	nd						nd
	27/1/76	21	nd	nd	10	T	17					nd
	25/2/76	77	nd	nd	13	2						nd
	15/3/76	78	nd	nd	17	2						nd
	12/7/76	76	T	nd	19	5						nd
	12/10/76	86	1.2	nd	18	3						14
Belleville	29/12/74	145			19	nd						nd
	2/3/75	200			15	nd						nd
	16/11/75	112			14	nd						nd
	16/2/76	68		2	10	nd	17			2		nd
	7/4/76	133	T	T	9	nd						5
	5/5/76	154	0.4	nd	13	nd						1
	22/6/76	241	1.1	nd	15	nd	115	nd	nd	6	nd	nd
	9/7/76	185	0.7	nd	16	nd						nd
	16/7/76	153	nd	nd	13	nd						nd
	3/8/76	199	0.5	1	14	nd						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Belleville (Cont'd)	19/10/76	119	1.5	nd	15	nd						nd
	23/11/76	80	nd	nd	11	nd						nd
	15/12/76	75	nd	nd	12	nd						nd
Blenheim	25/5/76	24	0.1	nd	7	1	17		nd	3	1	nd
	7/16/76	32	0.7	nd	9	3	18		T	4	1	15
	28/6/76	18	nd	nd	6	2	11		2	4	nd	nd
	26/7/76	36	T	nd	11	3						nd
	30/8/76	25	nd	3	6	2						nd
	27/9/76	43	0.6	nd	13	3						nd
	25/10/76	27	0.4	nd	8	2						nd
	29/11/76	22	nd	nd	12	3						nd
Bowmanville	13/3/75	7			6	nd						12
	9/9/75	22			14	nd						nd
	17/3/76	15	nd	nd	11	5						nd
	12/5/76	20	0.4	1	11	5	16		nd	6	3	nd
	9/6/76	22	0.3	T	12	5	8		nd	6	3	6
	8/3/76	51	nd	T	19	5						nd
	9/1/76	60	0.5	11	16	6						nd
	10/1/76	29	0.4	nd	16	6						nd
	11/10/76	14	nd	nd	7	4						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Brantford	4/12/74	129			33	nd						nd
	10/1/75	154			44	nd						nd
	11/1/75	108			44	4						nd
	13/1/75	147			38	nd						nd
	14/1/75	156			32	nd						nd
	21/2/75	130			52	2						nd
	25/3/75	156			29	nd						nd
	7/4/75	149			30	nd						nd
	10/4/75	140			12	nd						nd
	11/4/75	163			16	nd						nd
	12/4/75	167			17	nd						nd
	13/4/75	144			13	nd						nd
	14/4/75	163			14	nd						nd
	15/4/75	162			14	nd						nd
	16/4/75	162			14	nd						nd
	17/4/75	160			11	nd						nd
	6/8/75	137			nd	nd						nd
	3/9/75	256			35	nd						nd
	16/2/76	73		nd	11	2	35			4		nd
	26/2/76	99		2	13	1						nd
	6/4/76	193	2	6	22	nd						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Brantford (Cont'd)	3/5/76	89		nd	11	nd	46		2	8	nd	nd
	22/7/76	291	0.8	nd	25	2						nd
	28/7/76	250	0.9	nd	23	1						nd
	3/8/76	250	0.6	nd	21	1						nd
	9/9/76	128	nd	nd	19	2						nd
	4/10/76	158	1.4	nd	21	nd						nd
	18/10/76	184	2.5	11	27	nd						nd
	25/10/76	158	1.3	2	22	nd						nd
	1/11/76	154	0.7	nd	23	1						nd
	29/11/76	144	0.8	nd	18	nd						nd
Burlington	17/6/76	15	T	nd	9	4	9		1	5	3	nd
	29/7/76	17	nd	nd	9	4						nd
	26/8/76	17	nd	nd	8	4						nd
	21/10/76	37	nd	nd	10	4						nd
	18/11/76	7	nd	nd	7	4						nd
Cayuga	4/12/74	72			14	nd						nd
	13/1/75	36			13	nd						nd
	7/4/75	72			18	nd						nd
	10/4/75	105			10	nd						nd
	11/4/75	112			20	nd						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Cayuga (Cont'd)	12/4/75	129			20	nd						nd
	13/4/75	144			21	nd						nd
	14/4/75	157			25	nd						nd
	15/4/75	122			20	nd						nd
	16/4/75	119			17	nd						nd
	17/4/75	120			18	nd						nd
	6/8/75	208			37	nd						nd
	4/9/75	193			35	nd						nd
	26/11/75	178			37	nd						nd
	17/2/76	8		nd	1	nd	5			nd		nd
	24/2/76	1		nd	1	nd						nd
	5/4/76	29	T	T	8	nd						nd
	18/5/76	90	0.9	nd	15	nd	61		nd	8	nd	nd
	8/6/76	102	3.8	13	26	3						nd
	16/6/76	166	2.2	9	36	3						nd
	14/7/76	127	nd	nd	19	2						nd
	9/7/76	256	0.5	nd	27	2						nd
	19/7/76	127	1.1	nd	14	12						nd
	3/8/76	77	nd	nd	12	1						nd
	9/8/76	184	0.8	nd	26	2						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Chatham	9/3/75	45			26	7						nd
	28/1/76	19		nd	9	T	14		nd	6	T	nd
	18/5/75	12	0.1	nd	7	3	10		nd	3	2	nd
	12/8/75	22	nd	nd	10	6						nd
	15/11/76	19	nd	nd	9	5						nd
Dresden	23/4/75	122			9	nd						nd
	12/8/75	134			19	nd						18
	5/4/76	77	nd	nd	12	2						nd
Elgin	10/3/75	57			25	8						nd
	12/8/75	50			24	6						nd
	29/1/76	31			11	6	18			7	nd	nd
	1/3/76	49	nd	nd	17	4						2
	5/4/76	39	nd	nd	nd	nd						nd
	3/5/76	30	0.3	nd	12	4	13		nd	4	nd	nd
	7/6/76	28	nd	nd	1	4	14		T	5	2	2
	5/7/76	52	T	T	17	5	36		7	13	1	nd
	3/8/76	51	nd	nd	17	5						nd
	7/9/76	51	nd	nd	15	5						nd
	12/10/76	74	nd	nd	12	3						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Georgetown	24/3/76	6	nd	nd	nd	nd						nd
Goderich	11/8/75	33			10	14						nd
	24/2/76	71	T	nd	12	T						nd
	22/3/76	71	nd	nd	11	1						3
	5/5/76	55	0.5	nd	11	1	90		nd	12	nd	nd
	7/6/76	40	T	T	nd	nd	17		nd	5	nd	nd
	13/7/76	46	nd	nd	12	3						nd
	3/8/76	10	nd	nd	1	nd						nd
	12/10/76	27	nd	nd	14	4						nd
Grand Bend	26/12/75	22	nd	nd	12	2						nd
	11/8/75	32	nd	nd	13	5						74
	29/6/76	24	0.2	T	6	2						nd
	8/7/76	42	nd	nd	9	3						nd
	5/8/76	28	nd	nd	5	2						nd
	2/9/76	14	nd	nd	5	2						nd
Guelph	19/2/74	nd			nd	nd						nd
Haileybury	10/3/75	41			nd	nd						7
Halton	27/5/76	11	0.4	nd	8	3	5		nd	2	1	nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Harrow-Colchester	17/5/76	52	0.6	2	13	3	33		nd	6	nd	nd
	25/5/76	74	0.7	1	22	5	40		2	11	5	nd
	21/6/76	87	nd	5	20	5	51		1	10	2	nd
	28/6/76	100	0.9	4	13	3	70		nd	10	nd	nd
	26/7/76	108	nd	T	24	6						nd
	23/8/76	89	nd	20	5	5						nd
	30/8/76	101	nd	nd	22	7						nd
	20/9/76	93	2.7	6	27	6						nd
	27/9/76	70	0.5	nd	20	6						nd
	18/10/76	44	0.3	nd	12	3						nd
	25/10/76	58	0.5	2	17	4						nd
	29/11/76	26	nd	nd	13	nd						nd
	20/12/76	43	nd	nd	27	nd						nd
	2/1/75	51		3	4	nd						nd
Hawkesbury	15/10/75	36			nd	nd						nd
Kingston	5/11/75	24			10	nd						3
	5/4/76	31	T	2	18	5						nd
	4/5/76	61	0.3	nd	14	1	40		1	6	1	nd
	2/6/76	49	0.5	nd	15	3	27		1	10	3	nd
	5/7/76	40	0.1	T	12	4	21		1	4	nd	nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Kingston (Cont'd)	3/8/76	33	nd	T	15	4						nd
	7/9/76	35	0.7	nd	12	5						nd
	27/9/76	37	0.5	nd	17	6						nd
	1/11/76	20	nd	nd	11	5						nd
Markham - Don Mills Plant	3/12/74	nd			5	21						nd
	18/8/75	6			4	7						nd
John St. Plant	3/12/74	36			41	38						nd
Napanee	2/3/75	19			5	nd						nd
	6/11/75	70			12	nd						nd
	18/5/76	80	0.6	nd	7	nd	35		nd	2	nd	nd
	7/6/76	145	1.5	nd	9	2	91		nd	3	nd	nd
	13/7/76	87	nd	nd	12	nd						nd
	18/11/76	44	nd	nd	6	nd						nd
Newcastle	14/4/76	22	6	T	15	6						nd
	7/7/76	18	T	nd	10	5	7		1	4	1	nd
Niagara-on-the-Lake	15/12/74	29			18	4						nd
	7/8/75	27			14	3						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Oakville	16/6/76	21	0.2	F	11	5						nd
	15/7/76	23	nd	nd	10	4						nd
	8/9/76	22	nd	nd	9	5						nd
	7/10/76	18	1.8	nd	11	6						nd
	20/10/76	13	nd	nd	13	5						nd
	18/11/76	12	nd	nd	9	5						nd
Ottawa - Britannia WTP	17/4/75	11			nd	nd						nd
	5/2/76	8			nd	nd						nd
	22/9/76	147	0.8	nd	4	nd						nd
Lemieux WTP	17/4/75	6			nd	nd						nd
	22/7/76	104	.9	nd	3	nd						nd
Pembroke	3/1/75	58			3	nd						nd
	15/10/75	85			nd	nd						nd
	5/2/76	26	nd	nd	nd	nd						nd
	17/9/76	90	nd	nd	1	nd						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Port Lambton	29/1/76	8	7	nd	4	3						nd
	30/1/76	19	T	nd	11	4						nd
	24/2/76	16	T	nd	7	2						nd
	1/6/76	11	nd	nd	5	2	8		T	3	1	nd
	5/7/76	36	nd	nd	9	4						nd
	3/8/76	39	0.2	nd	13	5						nd
	2/9/76	33	nd	nd	8	4						nd
	1/11/76	19	nd	nd	8	3						nd
Prescott	2/1/75	33			20	5						nd
	14/10/75	16			nd	nd						11
	2/2/76	26		nd	5	nd						nd
Renfrew	15/10/75	56			nd	nd						nd
	10/2/76	72		nd	2	nd						nd
	8/6/76	29	nd	nd	2	nd	22		2	6	5	nd
Sarnia	11/8/75	32			10	nd						nd
	26/1/76	14	nd	nd	6	T						nd
Sault Ste.Marie	5/3/75	12			nd	nd						2
	19/5/76	12	nd	nd	nd	nd	7		nd	nd	nd	nd
	5/8/76	11	nd	nd	nd	nd						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Sault Ste. Marie (Cont'd	8/9/76	10	0.6	nd	nd	nd						nd
Smiths Falls	10/4/75	4			nd	nd						nd
	7/5/75	71			4	nd						nd
	9/8/75	37			nd	nd						nd
	11/8/75	35			3	nd						nd
	5/4/76	25	0.1	nd	2	nd						nd
	3/5/76	65	0.5	nd	4	nd						nd
	7/6/76	62	1	nd	3	nd	45		T	1	nd	nd
Sombra	29/1/76	50	8	nd	12	6						nd
	24/2/76	27	4	nd	5	4						nd
Southampton	5/4/76	83	3	T	11	nd						3
	3/5/76	46	0.6	nd	13	4	29		1	5	2	38
	8/6/76	43	0.6	nd	10	2	27		nd	6	nd	16
	14/9/76	38	nd	nd	11	4						nd
	5/10/76	39	nd	nd	14	5						nd
	9/11/76	30	nd	nd	8	2						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Sudbury - Coniston WTP	25/2/76	92			2	nd						nd
	10/3/76	74	nd	nd	4	nd						nd
	10/5/76	100	0.4	1	4	nd	73		1	2	nd	nd
	16/6/76	126	nd	nd	6	nd	90		nd	1	nd	nd
	14/7/76	178	0.5	nd	6	nd						nd
	17/8/76	154	0.5	nd	8	nd						nd
	15/9/76	141	nd	nd	10	nd						nd
	18/10/76	125	1.4	nd	3	nd						nd
	17/11/76	59	nd	nd	nd	nd						nd
Lake Ramsey WTP	23/2/76	34	nd	nd	nd	nd						nd
	20/4/76	27	nd	nd	2	nd						nd
	5/4/76	28	nd	nd	9	2						nd
	3/5/76	47	0.3	nd	12	2	25		nd	4	nd	nd
	7/6/76	49	0.5	nd	11	4	26		nd	7	1	nd
	19/7/76	31	nd	nd	6	1						nd
	16/8/76	60	nd	nd	11	2						nd
	13/9/76	56	1.8	nd	12	1						54
	25/10/76	46	.5	3	13	2						40

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Thunder Bay - Bare Pt. WTP	25/2/75	52			7	nd						nd
	29/4/75	41			nd	nd						4
	30/9/75	20			4	nd						nd
	7/10/75	41			9	nd						nd
	2/10/75	36			11	nd						nd
	28/10/75	32			11	nd						nd
	4/11/75	29			5	3						nd
	10/11/75	23			5	1						nd
	18/11/75	27			24	nd						nd
	2/12/75	26			5	nd						nd
	12/4/76	26	3	nd	5	1						nd
	20/4/76	32	0.4	nd	5	nd	22		2	4	3	nd
	4/5/76	34	0.3	nd	6	1	20		nd	2	nd	nd
	10/5/76	21	0.1	nd	2	nd	8		nd	1	nd	nd
	11/5/76	55	nd	nd	7	nd	30		1	4	2	nd
	27/4/76	33	0.9	nd	3	nd						nd
	13/7/76	35	nd	nd	5	nd						nd
Loch Lomond WTP	25/2/75	130			3	nd						nd
	25/4/75	23			32	36						23

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Toronto - Lakeview WTP	15/1/75	6			9	5						nd
	26/2/75	5			5	1						nd
	8/5/75	10			7	nd						nd
	10/9/75	6			8	nd						nd
	17/5/76	3	nd	nd	2	1	2		nd	nd	nd	nd
RC Harris WTP	5/12/74	19			13	6						12
	2/10/75	nd			nd	nd						nd
	16/2/76	16		2	11	5						nd
	15/3/76	7	nd	nd	3	1						nd
	9/3/76	3	nd	nd	3	2						nd
	13/4/76	7	3	nd	3	1						nd
	4/5/76	7	0.4	nd	3	2	2		nd	1	1	nd
	28/10/76	7	nd	nd	6	3						nd
Westerly WTP	9/3/76	5	nd	nd	4	2						nd
	15/3/76	8	nd	nd	5	12						nd
	13/4/76	10	0.4	T	5	2						2
	4/5/76	9	0.3	nd	5	1	4		nd	1	1	nd
	13/7/76	10	nd	nd	6	3						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Trenton	9/2/76	116		nd	6	nd						nd
	22/3/76	92	nd	nd	7	nd						nd
	30/3/76	178	nd	nd	9	nd						nd
	11/4/76	178	nd	nd	11	1						2
	10/5/76	164	0.5	2	9	1	101		2	5	1	nd
	25/5/76	168	0.6	nd	9	nd	122		3	6	nd	nd
	14/6/76	152	1.7	T	9	nd	144		2	8	nd	5
	29/6/76	104	0.3	T	7	nd	116		nd	4	nd	nd
	3/8/76	149	nd	T	12	nd						nd
	18/8/76	219	nd	nd	11	nd						nd
	31/8/76	148	1.3	9	11	nd						nd
	12/10/76	120	2.2	nd	13	nd						nd
	1/11/76	95	nd	nd	nd	nd						nd
Union WTP	9/3/75	31			16	5						nd
	12/8/75	61			19	nd						nd
	28/1/76	10		nd	6	4						nd
	27/4/76	36	0.4	nd	12	3	26		2	8	5	nd
	25/5/76	46	0.6	nd	12	3	27		1	7	2	nd
	28/6/76	59	nd	T	17	3	51		nd	11	3	nd
	26/7/76	66	nd	1	19	5						nd
	18/10/76	38	0.4	nd	11	3						nd

LOCATION	DATE SAMPLED	DAI ug/l					GS ug/l					DAI
		CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃	CCl ₄	C ₂ HCl ₃	CHCl ₂ Br	CHBr ₂ Cl	CHCl ₃ (raw water)
Union WTP (Cont'd)	15/11/76	25	nd	nd	12	5						nd
Whitchurch - Stouffville	12/5/75	60			8	4						nd
Windsor	10/3/75	66			30	3						nd
	9/5/75	41			12	3						nd
	12/8/75	13			17	nd						nd
	27/1/76	14		nd	8	T						nd
	3/5/76	30	0.2	nd	1	nd	16		nd	nd	nd	nd
	3/6/76	45	0.5	nd	15	3	29		nd	8	3	nd
	5/8/76	54	0.3	nd	16	5						nd
	3/9/76	47	nd	nd	17	6						nd
	1/11/76	35	nd	nd	14	5						nd

APPENDIX II

RAW WATER SOURCES

<u>LOCATION</u>	<u>RAW WATER SOURCE</u>
Acton	Well
Amherstburg	Detroit River
Belleville	Moirs River
Bowmanville	Lake Ontario
Brantford	Grand River
Burlington	Lake Ontario
Cayuga	Grand River
Chatham	Thames River
Dresden	Sydenham River
Elgin	Lake Erie
Georgetown	Well
Goderich	Lake Huron
Grand Bend	Lake Huron
Guelph	Well
Haileybury	Lake Timiskaming
Halton	Well
Harrow-Colchester	Lake Erie
Hawkesbury	Ottawa River
Kingston	Lake Ontario
Markham - Don Mills	Well
- John St.	Well
Napanee	Napanee River
Newcastle	Lake Ontario
Niagara-on-the-Lake	Lake Ontario
Oakville	Lake Ontario
Ottawa- Britannia	Ottawa River
- Lemieux	Ottawa River
Pembroke	Ottawa River
Port Lambton	Lake St. Clair
Prescott	St. Lawrence River
Renfrew	Bonnechere River
Sarnia	Lake Huron
Sault Ste. Marie	Lake Superior

<u>LOCATION</u>	<u>RAW WATER SOURCE</u>
Smiths Falls	Rideau River
Sombra	St. Clair River
Southampton	Lake Huron
Sudbury	
- Coniston	Lake Wanapitei
- Lake Ramsey	Lake Ramsey
Thunder Bay	
- Bare Pt.	Lake Superior
- Loch Lomond	Loch Lomond
Toronto	
- Lakeview	Lake Ontario
- R.C. Harris	Lake Ontario
- Westerly	Lake Ontario
Trenton	Trenton River
Union	Lake Erie
Whitchurch - Stouffville	Well
Windsor	Detroit River

APPENDIX III

DETERMINATION OF PESTICIDES, HERBICIDES AND
PCB'S IN RAW AND FINISHED DRINKING WATERS.

ALL CONCENTRATIONS ARE EXPRESSED IN ug/l

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Amherstburg				
- treated	18/12/74	nd	nd	nd
- before filters	"	nd	nd	Atrazine 0.05
- raw	9/3/75	nd	nd	nd
- treated	"	nd	nd	nd
Belleville				
- raw	29/12/74	nd	nd	nd
- before filters	"	nd	nd	nd
- raw	2/3/75	nd	nd	nd
- before filters	"	nd	nd	nd
- treated	"	nd	nd	nd
Bowmanville				
- raw	13/3/75	nd	nd	nd
- treated	"	nd	nd	nd
- raw	6/10/75	nd	nd	nd
- treated	6/10/75	nd	nd	nd
Brantford				
- raw	4/12/74	Dieldrin-trace	nd	Atrazine 0.25
- treated		" "	nd	0.20
- raw	10/1/75	nd	nd	nd
-treated		nd	nd	nd

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Brantford (Cont'd)				
- raw	14/2/75	nd	nd	Atrazine 0.16, Simazine 0.09
- treated		nd	nd	Atrazine 0.21, Simazine 0.06
- raw	21/2/75	nd	nd	Atrazine 0.1
- treated		nd	nd	nd
- treated	7/4/75	nd	nd	Atrazine 0.21
- raw	10/4/75	nd	nd	0.29
- treated	"	nd	nd	0.26
- raw	11/4/75	nd	nd	0.35
- treated		nd	nd	0.26
- raw	12/4/75	nd	nd	0.25
- treated		nd	nd	0.23
- raw	13/4/75	nd	nd	0.40
- treated		nd	nd	0.27
- raw	14/4/75	nd	nd	0.33
- treated		nd	nd	0.31
- raw	15/4/75	nd	nd	0.28
- treated		nd	nd	0.35
- raw	16/4/75	nd	nd	0.25
- treated		nd	nd	0.33
- raw	17/4/75	nd	nd	0.25
- treated		nd	nd	0.42

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Cayuga				
- raw	4/12/74	Dieldrin Trace	nd	Atrazine 0.41
- treated		" Trace	nd	0.45
- raw	14/2/75	nd	nd	Atrazine 0.15, Simazine trace
- treated		nd	nd	Atrazine 0.10 Simazine 0.05
- treated	7/4/75	nd	nd	Atrazine 0.12
- raw	10/4/75	nd	nd	0.37
- treated	"	nd	nd	0.28
- raw	11/4/75	nd	nd	0.33
- treated	"	nd	nd	0.24
- raw	12/4/75	nd	nd	0.34
- treated	"	nd	nd	0.42
- raw	13/4/75	nd	nd	0.32
- treated	"	nd	nd	0.36
- raw	14/4/75	nd	nd	0.42
- treated	"	nd	nd	0.29
- raw	15/4/75	nd	nd	0.40
- treated	"	nd	nd	0.39
- raw	16/4/75	nd	nd	0.32
- treated	"	nd	nd	0.25
- raw	17/4/75	nd	nd	0.50
- treated	"	nd	nd	nd

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Chatham				
- raw	9/3/75	nd	nd	nd
- treated		nd	nd	nd
Dresden				
- raw	23/4/75	nd	nd	Atrazine 0.57
- treated	"	nd	nd	0.40
- raw	18/12/75	nd	nd	nd
- treated	"	nd	nd	nd
Elgin				
- raw	10/3/75	nd	nd	nd
- treated	"	nd	nd	nd
Fort Francis				
- raw	7/5/76	nd	nd	nd
- treated	"	nd	nd	nd
Goderich				
- raw	24/4/75	nd	nd	Atrazine 0.07
- treated	"	nd	nd	0.07
Grand Bend				
- raw	26/2/75	nd	nd	nd
- treated	"	nd	nd	nd

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Guelph				
- raw	19/12/74	nd	nd	nd
- Arkell Spring	"	nd	nd	nd
- Canter's Well	"	nd	nd	nd
- raw #7	"	nd	nd	nd
- raw #6	"	nd	nd	Atrazine trace
Haileybury				
- raw	10/3/75	nd	nd	nd
- treated	"	nd	nd	nd
Hawkesbury				
- raw	2/1/75	nd	nd	nd
- treated	"	nd	nd	nd
Markham (Don Mills)				
- raw	18/8/75	nd	nd	nd
- treated	"	nd	nd	nd
Niagara-on-the-Lake				
- raw	15/12/74	lindane 0.03 α -BHC 0.02 β -BHC 0.006	nd nd nd	Atrazine trace

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Niagara-on-the-Lake (Cont'd)				
- treated	15/12/74	lindane 0.02 α -BHC 0.01 β -BHC 0.001	nd nd nd	Atrazine 0.05
- raw	9/10/75	nd	nd	nd
- treated	"	nd	nd	nd
Napanee				
- raw	2/3/75	nd	nd	nd
- treated	"	nd	nd	nd
Ottawa (Lemieux)				
- raw	17/4/75	nd	nd	nd
- treated	"	nd	nd	nd
(Britannia)				
- raw	17/4/75	nd	nd	nd
- treated	"	nd	nd	nd
Pembroke				
- raw	3/1/75	nd	nd	nd
- treated	"	nd	nd	Atrazine trace
Sault Ste. Marie				
- raw	5/3/75	nd	nd	nd
- treated	"	nd	nd	nd

LOCATION	DATE SAMPLED	ORGANOCHLORINE PESTICIDES	POLYCHLORINATED BIPHENYLS	TRIAZINE HERBICIDES
Sudbury				
(Coniston)				
- raw	25/2/75	nd	nd	nd
- treated	"	nd	nd	nd
Thunder Bay				
(Bare Pt.)				
- raw	25/2/75	nd	nd	nd
- treated	"	nd	nd	nd
(Loch Lomand)				
- raw	25/2/75	nd	nd	nd
- treated	"	nd	nd	nd
Toronto (Lakeview)				
- raw	26/2/75	nd	nd	nd
- treated	"	nd	nd	Atrazine 0.08
Union				
- raw	9/3/75	nd	nd	nd
- treated	"	nd	nd	nd
Windsor				
- raw	10/3/75	nd	nd	nd
- treated	"	nd	nd	nd

APPENDIX IV

GAS CHROMATOGRAPHY/MASS SPECTROMETRY ANALYSES

OF RAW AND FINISHED DRINKING WATER

<u>LOCATION</u>		<u>DATE SAMPLED</u>	<u>CONFIRMATION</u>
Belleville	Treated	2/3/75	Chloroform
Brantford	Treated	13/1/75	Chloroform, Bromodichloromethane, Chlorodibromomethane
Brantford	Treated	21/2/75	Chloroform, Bromodichloromethane, Chlorodibromomethane
Brantford	Treated	25/3/75	Chloroform
Brantford	Treated	25/3/75	Chloroform, Bromodichloromethane, Chlorodibromomethane, Toluene
Brantford	Treated	7/4/75	Chloroform, Bromodichloromethane, Benzene, Ethylbenzene
Brantford	Treated	10/4/75	Chloroform
Brantford	Treated	10/4/75	Chloroform
Brantford	Treated	10/4/75	Chloroform
Brantford	Treated	12/4/75	Chloroform
Brantford	Treated	13/4/75	Chloroform, Bromodichloromethane, Toluene, Xylenes
Brantford	Treated	14/4/75	Chloroform, Bromodichloromethane, Toluene, Xylenes, Ethyltoluenes, Diethylbenzenes
Brantford	Raw	14/4/75	nd
Brantford	Treated	15/4/75	Chloroform
Brantford	Raw	16/4/75	nd
Brantford	Treated	17/4/75	Chloroform
Brantford	Treated	6/8/75	Chloroform, Bromodichloromethane
Brantford	Raw	6/8/75	nd
Brantford	Treated	6/8/75	Chloroform, Bromodichloromethane, Chlorodibromomethane, Hexane, Xylenes
Ottawa	Treated	17/4/75	Chloroform
Cayuga	Treated	7/4/75	Chloroform, Bromodichloromethane, Benzene, Toluene, Xylenes, Ethylbenzene, Cymene, Trimethylbenzene

<u>LOCATION</u>		<u>DATE SAMPLED</u>	<u>CONFIRMATION</u>
Cayuga	Treated	10/4/75	Chloroform, Toluene, Cymene
Cayuga	Treated	10/4/75	Chloroform, Bromodichloromethane Toluene, Ethylbenzene
Cayuga	Treated	12/4/75	Methylene Chloride, Chloroform, Bromodichloromethane, Benzene, Toluene, Xylenes, Ethyltoluenes Diethylbenzenes
Cayuga	Raw	12/4/75	nd
Cayuga	Treated	13/4/75	Chloroform, Bromodichloromethane, Benzene
Cayuga	Raw	13/4/75	nd
Cayuga	Raw	13/8/75	nd
Cayuga	Treated	13/8/75	Chloroform, Bromodichloromethane, Ethylbenzene, Xylenes
Dresden	Treated	23/4/75	Chloroform, Bromodichloromethane,
Goderich	Treated	24/4/75	Chloroform, Bromodichloromethane, Dichlorobenzene
Grand Bend	Treated	26/2/75	Chloroform
Ottawa	Treated	17/4/75	Chloroform, Benzene, Toluene
Markham	Treated	17/4/75	Chloroform, Bromodichloromethane Chlorodibromomethane
Pt. Lambton	Treated	29/1/76	Methylene Chloride, Tetrachloro- ethane, Xylenes
Smith Falls	Treated	10/4/75	Chloroform
Smith Falls	Raw	7/5/75	nd
Smith Falls	Treated	7/5/75	Chloroform, Bromodichloromethane, Benzene
Smith Falls	Ozonated	7/5/75	Benzene, Toluene
Smith Falls	Treated	9/8/75	Chloroform
Smith Falls	Ozonated	9/8/75	Hexane
Smith Falls	Raw	11/8/75	nd
Smith Falls	Treated	11/8/75	Chloroform
Smith Falls	Ozonated	11/8/75	Chloroform, Toluene
Thunder Bay	Treated	25/2/75	Chloroform
Union	Treated	9/3/75	Chloroform, Bromodichloromethane, Toluene, Ethylbenzene, Cumene

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